
Section 206 Rhode Island

Analysis Of Flood Problem And Potential Solutions

Woonasquatucket River North Providence, Rhode Island

APRIL 1983



**US Army Corps
of Engineers**
New England Division

FLOOD PLAIN MANAGEMENT
TECHNICAL ASSISTANCE

WOONASQUATUCKET RIVER
NORTH PROVIDENCE, RHODE ISLAND

APRIL 1983
Corps of Engineers, New England Division
Waltham, Massachusetts

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I. INTRODUCTION

The Woonasquatucket River Basin lies entirely within the northwestern portion of Rhode Island. The watershed is bounded by the Blackstone River Basin on the north and east, the Pawtuxet on the south and west, with a small portion touching the Narragansett Bay Local Drainage Area on the southeast. The waterways within the basin were originally developed for textile manufacturing and processing. The needs of the textile industry were met by conservation storage from over 30 impoundments throughout the watershed. Fifteen of these impoundments have a surface area greater than 20 acres and total 1,224 acres of water surface area. The banks of the Woonasquatucket are principally developed for industrial and commercial entities with very little use for recreational purposes, partly due to the present water quality of the stream.

Flooding in the basin can occur any season of the year as a result of heavy rainfall alone or in combination with runoff from snowmelt. The magnitude of riverine flooding on the Woonasquatucket River is a function of storm rainfall and the resultant runoff from 36.9 square miles of drainage downstream of the impoundments mentioned above, as well as the magnitude and timing of the discharges of the initial storage capacity in these impoundments. Flooding along the Woonasquatucket most recently has occurred in March 1968, January 1979, and June 1982. The wide range of seasons in which recent flooding has occurred supports the fact that damage can be sustained anytime during the year.

The town of North Providence lies within the coastal plain area in the lower half of the Providence River drainage system emptying into Narragansett Bay. Geographically, North Providence has an area of 5.8 square miles and is surrounded by Providence to the south, Johnston to the west, Pawtucket to the east, and Smithfield and Lincoln to the north. The proximity to Narragansett Bay and the Atlantic Ocean results in many of the major storms dropping their precipitation in the form of rain, rather than snow. The flood plains within the community contain residential, commercial and industrial developments.

The Worcester Textile Company, a manufacturer of textile products employing approximately 700 people, is located on Greystone Avenue adjacent to the Woonasquatucket River. The firm has experienced flood damages three times within the last 15 years. The March 1968 flood resulted in 15 inches of water within the plant on the lowest floor, while the June 1982 flood resulted in 4 inches of water on the lowest floor. The company had approximately 2-1/2 hours lead time from when the potential for flooding was identified and water actually entered the plant in the June 1982 flood. Steps were taken to elevate inventory above the flooding and move motors to locations not impacted by the flooding. As a result, flood damage for the most part was limited to interior damage in the production area.

The facility is a multi-story structure of masonry construction. Although the facility is an old building, the structure appears to be in fairly good

condition. A total of eight doors at ground level on the west side of the building and a series of windows (currently enclosed with corrugated metal) in the same area face the Woonasquatucket River. Past flooding events have been of a magnitude that water enters the plant through the doorways, but not through the window openings. However, more severe flooding events could result in water entering the plant via both the doorways and windows. The most obvious method to approach the problem is to keep water outside the plant since damage will occur even when inventory and machinery can be protected. Measures which could be undertaken by the company to successfully mitigate flood damages at the site include flood proofing, both temporary and/or permanent, or a levee and concrete wall configuration with the associated pumping. Other flood damage reduction measures broader in scope include diversion channels, modification of downstream hydraulic structures, downstream channel improvements and upstream flood storage. Only measures directly implementable at the site are considered in this study.

II. PURPOSE AND AUTHORITY

The Worcester Textile Company requested assistance from the New England Division, Corps of Engineers in determining the severity of the flood problem at the plant and identifying alternative solutions to mitigate the flood hazard. The purpose of this report is to provide the firm with anticipated flood stages at the site for flooding events and develop preliminary cost estimates of measures which can be implemented by the firm to reduce flood damages.

Authority for Corps of Engineers participation in this effort is contained in Section 206 of the 1960 Flood Control Act (Public Law 86-645) which states

" . . The Secretary of the Army through the Chief of Engineers, Department of the Army, is hereby authorized to compile and disseminate information on floods and flood damages, including identification of areas subject to inundation by floods of various magnitudes and frequencies, and general criteria for guidance in the use of flood plain areas and to provide engineering advice to local interests for their use in planning to ameliorate the flood hazard. . ."

The Corps of Engineers has the authority to construct small flood control projects through provisions made in Section 205 of the 1948 Flood Control Act, as amended by Section 133(b) of the 1976 Water Resources Development Act. There is a Federal cost limitation of \$4 million on each project which includes all related costs for investigations, inspections, engineering preparation of plans and specifications, supervision, administration, and construction. A project is adopted under Section 205 only after full detailed investigation and study clearly shows the engineering feasibility and economic justification of the project proposed. Studies performed under this authority generally require a minimum 3-5 years from study initiation until completion of construction.

III. SCOPE

This report encompasses a determination of anticipated flood stages at the Worcester Textile Company plant and identification of alternative measures which can mitigate the flood hazard. A hydrologic and hydraulic analysis was completed to determine anticipated flood flows and corresponding stages along the Woonasquatucket River in the reach near the plant. High water marks from past flooding events and historical streamflow data from a gauging station downstream were used to develop the flood profiles in this area. Also, a fairly detailed evaluation of the existing interior drainage system was performed to determine the extent local drainage contributes to the flood problem.

An array of flood damage reduction measures were viewed as potential solutions to the flood problem at this location. The list of possible measures was narrowed based upon the physical characteristics of the structure and the local topography in the area. The two flood damage reduction measures which appear to be easily implementable and effective in reducing flood damages are a wall and levee system including the necessary interior drainage improvements or flood proofing the outside of the existing structure. Preliminary plans and cost estimates for a level of protection equal to a 100-year frequency flooding event have been developed for four different wall alignments and a flood proofing alternative. These preliminary layouts and cost estimates are by no means the equivalent of a final design. More detailed design work is required before construction can be initiated. This document serves as a planning guide, not as a final design before the initiation of construction.

IV. FLOOD DAMAGE REDUCTION MEASURES

A. Rearranging or Protecting Damageable Property

Within an existing structure, damageable property can often be placed in a less vulnerable location or protected in place. This measure can involve either minor or major modifications to the structure and/or selection of specific types of contents to be protected. It is something every property owner can implement to one degree or another.

The degree to which property can be rearranged and protected is site specific. The extent of implementation is dependent upon the depth and frequency of flooding; and the type, value, location, and mobility of the damageable property to be protected. Shallow flooding allows the use of protective types of measures where appliances, utilities, equipment and goods can be raised in place, surrounded, or enclosed. Where the hazard is more severe and inundation is to greater depths, property will need to be relocated to prevent damage.

Residual damage to both structures and contents will remain even when property is rearranged or protected. For these reasons, protection of damageable property seems to be more seriously considered when other measures are either not physically or economically feasible, or the depths of flooding are relatively shallow. The Worcester Textile Company currently utilizes this method to reduce flood damages. When flooding is imminent, the firm raises inventory off the floor and moves electric motors to other locations in the plant not susceptible to flooding. A detailed analysis of further applications of this measure at this particular site was not performed because steps of this type are already taken by the firm to reduce flood damages.

Advantages

- . Almost every property owner can implement this method to one degree or another.
- . It can be done on a per item basis, thus reducing the cost and allowing selective protection of high value contents.
- . A structure can continue to be used at its existing site.

Disadvantages

- . Damage can be reduced only on those items that can be relocated or protected.

B. Temporary and/or Permanent Closures

Structures whose exteriors are generally impermeable to water can be designed to keep floodwater out by installing watertight closures at openings such as doorways and windows. Due to the hydrostatic and buoyant pressures floodwaters exert on the building walls and basement, this method is better suited for commercial and industrial structures that are more structurally sound. While some seepage will probably always occur, it can be reduced by applying sealants to walls and floors, and providing floor drains where practical. Closures may be permanent or temporary in nature. Temporary closures are installed only during periods of flood threat, thereby requiring warning time before installation.

To prevent floodwaters from entering through exterior doors, installation of some form of flood proofing is needed, normally some type of flood shield or watertight door. These closures are usually fabricated of aluminum, steel, or wood and made to the height and width desired. In commercial or industrial structures, shields may be permanently installed on hinges or rollers for swinging or sliding into place, or as more often is the case, they can be stored nearby for installation during a flooding episode. Doorways and windows not needed can be permanently closed in with masonry or other impermeable material.

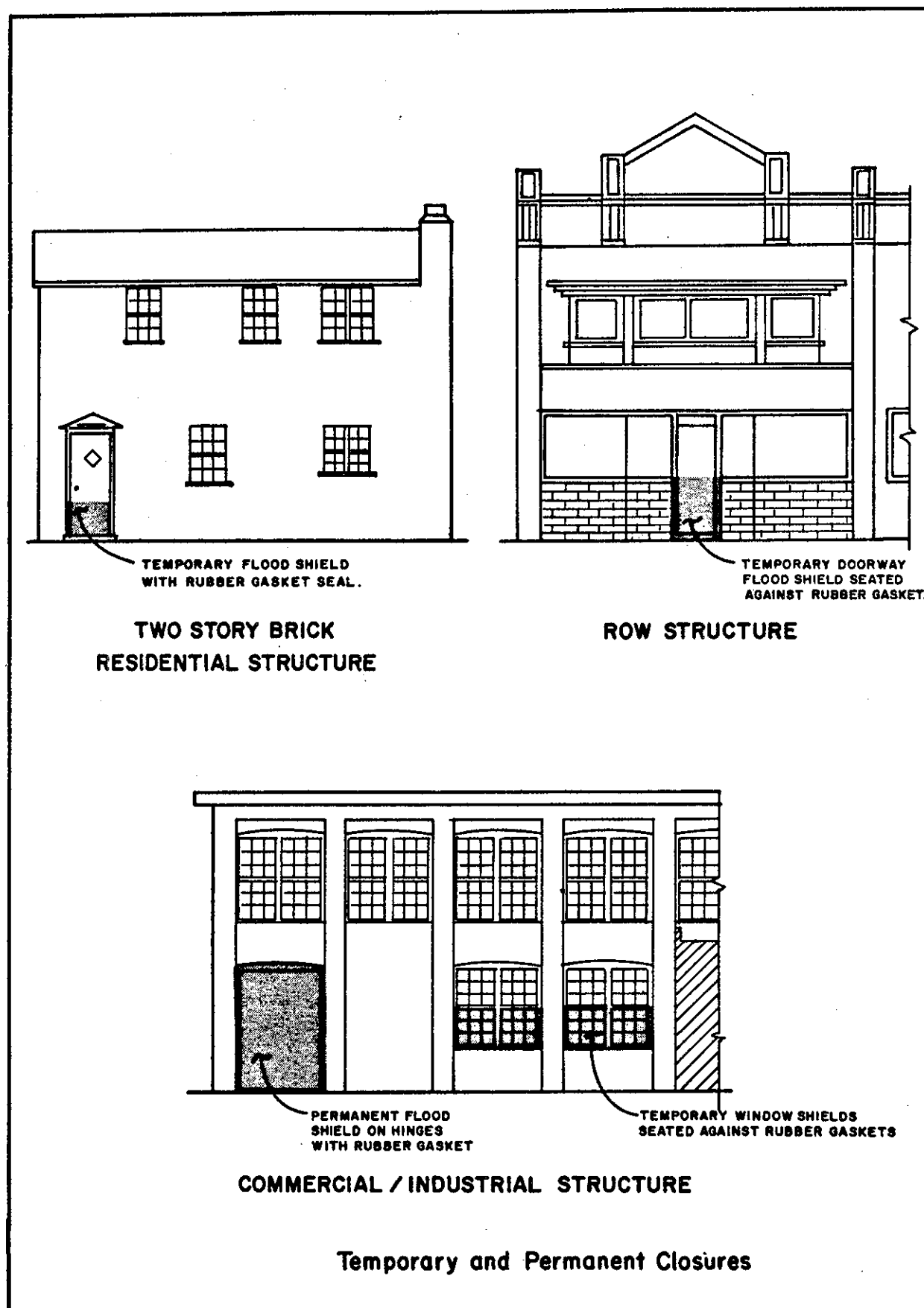


FIGURE 1

Normal window glass will take little water pressure and is especially vulnerable to breakage from floating debris. Flood shields also serve the purpose of protecting windows. Other measures, such as waterproofing sealants, are sometimes applied to generally impermeable walls to further reduce seepage. Sewer lines and other plumbing facilities can be flood proofed by installing non-backflow and gate valves. Despite these efforts, some water may still enter a structure even though it is generally water-tight, so sump pumps should be included to remove any seepage that might occur. The pump outlet should be installed outside the structure above the expected level of flooding.

Most structures, including commercial and industrial, are not designed to withstand hydrostatic pressures exerted on exterior walls, when water is not allowed into the structure, but stands against exterior walls. When water is prevented from entering a structure, walls become subject to forces which may cause failure and floors are subject to uplift forces which may cause buckling or flotation. It is particularly difficult to analyze the capability of existing structures to resist these forces because of the general lack of knowledge about workmanship and materials used during construction and about their present condition. Therefore, when discussing physical feasibility, the principal considerations are that (1) the exterior walls are impermeable or can be made so, (2) all openings below the flood level can be closed, and (3) the structure can withstand anticipated water pressures, including buoyancy.

Advantages

- . Flood proofing may be done on a selective basis to only those openings through which water enters and only to the height desired.
- . Easy and quick to implement.

Disadvantages

- . Applicable only to structures with brick or masonry type walls, which can structurally withstand the forces associated with flood depths.
- . May not be implementable at night or during absences.
- . May create a false sense of security and induce people to remain in a structure longer than they should.

C. Walls and Dikes

This approach usually involves a system or a combination of concrete floodwalls, earth rockfilled dikes, and appurtenant facilities for confining flood flows within the channel or floodway. A wall and dike system is

generally referred to as a local protection project because they provide protection to localized, high risk flood-prone areas located behind the dike system. These walls and dikes can vary greatly in size depending on the depths of anticipated flooding. When depths of flooding are not severe (less than 5 feet) individual or small groups of structures can be protected by small earthen dikes and/or walls.

Dikes are usually constructed with an impervious inner core to prevent water seepage. Slope protection can be combined with a levee if erosion is a problem. Dikes can be designed to be compatible with many landscapes, and at the same time serve to control floodwaters. Walls may be of brick, stone, or other material which is impermeable and capable of resisting the physical forces associated with flooding. In urban areas walls, usually limited to 3-5 feet in height, can be constructed along property lines like a fence or attached to the exterior walls of a structure. Where access openings are required, capability must exist to close them during floods. This generally means providing a flood gate which can either be stored on the site and installed when needed, or placed on hinges or rollers for automatic or semiautomatic closure.

A problem which must be addressed is accumulation of precipitation, seepage and runoff from roof drains inside the wall or dike, which then causes water damage to the protected property. This problem can be resolved by including a low-lying sump area to collect the drainage and a pump to remove the water. The pump discharge must be located above the design flood stage.

One particular advantage of a wall or dike, is that it is not limited to a particular type or size of structure and is feasible for any residential, commercial or industrial property. The question of physical feasibility centers on site conditions such as topography, available space, and compatibility with existing uses.

Advantages

- . Not dependent upon the site, type, or condition of property to be protected.
- . Protects all property associated with a structure.
- . Can provide privacy and security in addition to flood protection.

Disadvantages

- . Dependent upon site conditions: topography, property lines, available space, soil conditions, viscosity and depth of flooding, and location of floodwater relative to flooding.
- . May require access openings which must be closed during a flood, therefore requiring some type of flood forecasting system.

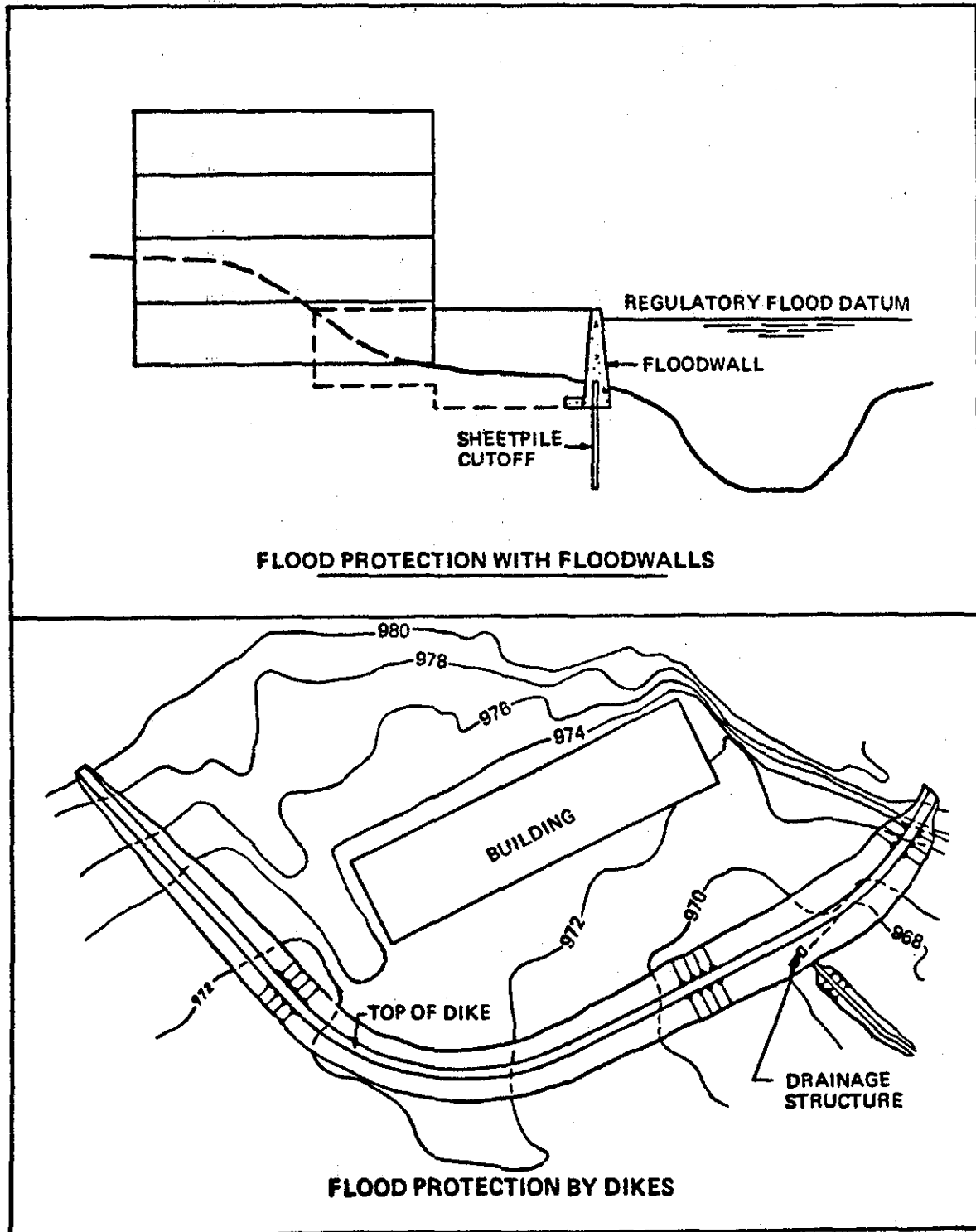


FIGURE 2

Steps must be taken to ensure that utilization of closures of walls and dikes will not worsen the affects of flooding during periods of high water. Proper design and construction of closures is a must because damages resulting from flooding would be much more severe than normal if the exterior walls of the structure buckled from the hydrostatic forces. In a like manner, the breaching or failure of a floodwall or levee could result in severe flood damage from the sudden release of the water stored behind the protection. In each instance the safety of individuals in the vicinity would be jeopardized to a greater degree than if no flood protection measures were present at the location. Precautionary actions applicable to the use of closures or floodwalls and levees as a flood damage reduction measure are outlined in Table 1.

V. HYDROLOGIC INFORMATION AND ANALYSIS

This portion of the report presents hydrologic information and analysis pertinent to flood control studies at Worcester Textile Company on the Woonasquatucket River in the town of Centerdale, Rhode Island. Included are sections on watershed description, climatology, flood history, flood frequencies, and hydrologic engineering analysis of various flood control plans.

Worcester Textile Company is located on the left bank of the Woonasquatucket River approximately 6 miles upstream from its confluence with the Providence River in Providence, Rhode Island. The Woonasquatucket watershed is shown on Plate 1. Flooding at Worcester Textile Company occurs during high riverflows as a result of either overbank flows from the Woonasquatucket River, or backup from storm drains that outlet to the river. The Worcester Textile Company site is shown on Plate 2.

A. Watershed Description

The Woonasquatucket River has a total drainage area of 51.5 square miles and is located mainly within the towns of Smithfield, Johnston, North Providence and Providence. It originates in North Smithfield and flows in a southerly direction into Stillwater Reservoir where it is joined by the Stillwater River. The river then flows in a southerly direction through several mill ponds: Stillwater, Capron and Georgiaville Ponds. The Worcester Textile Company property is located about 2 miles downstream of Georgiaville Pond and the drainage of the river at that location is about 38 square miles. The river has a total length of 19 miles and is joined by its principal tributary, the Moshassuck (D.A. = 23.3 square miles), at a distance of 1.2 miles above its mouth. The USGS has maintained a stream gaging station on the Woonasquatucket River at Centerdale, near US Highway 44, since 1942. The drainage area at the gage site is 38.3 square miles. The watershed ranges in elevation from about 260 feet NGVD in the headwaters to sea level at its mouth and has an average slope of about 13 feet per mile. Runoff from the watershed above Centerdale is hydrologically very "sluggish" due to the surcharge storage

TABLE 1

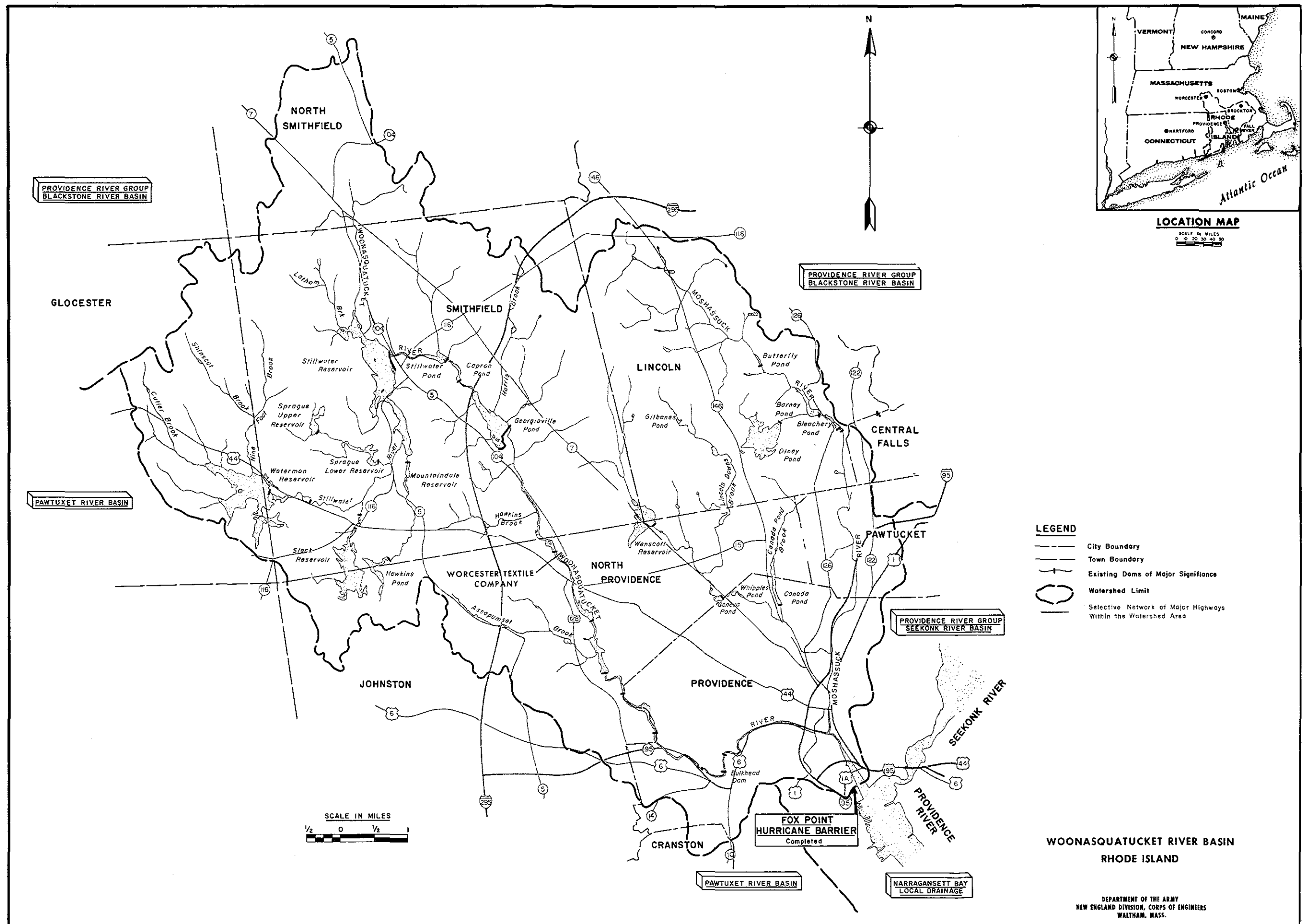
PRECAUTIONARY ACTIONS

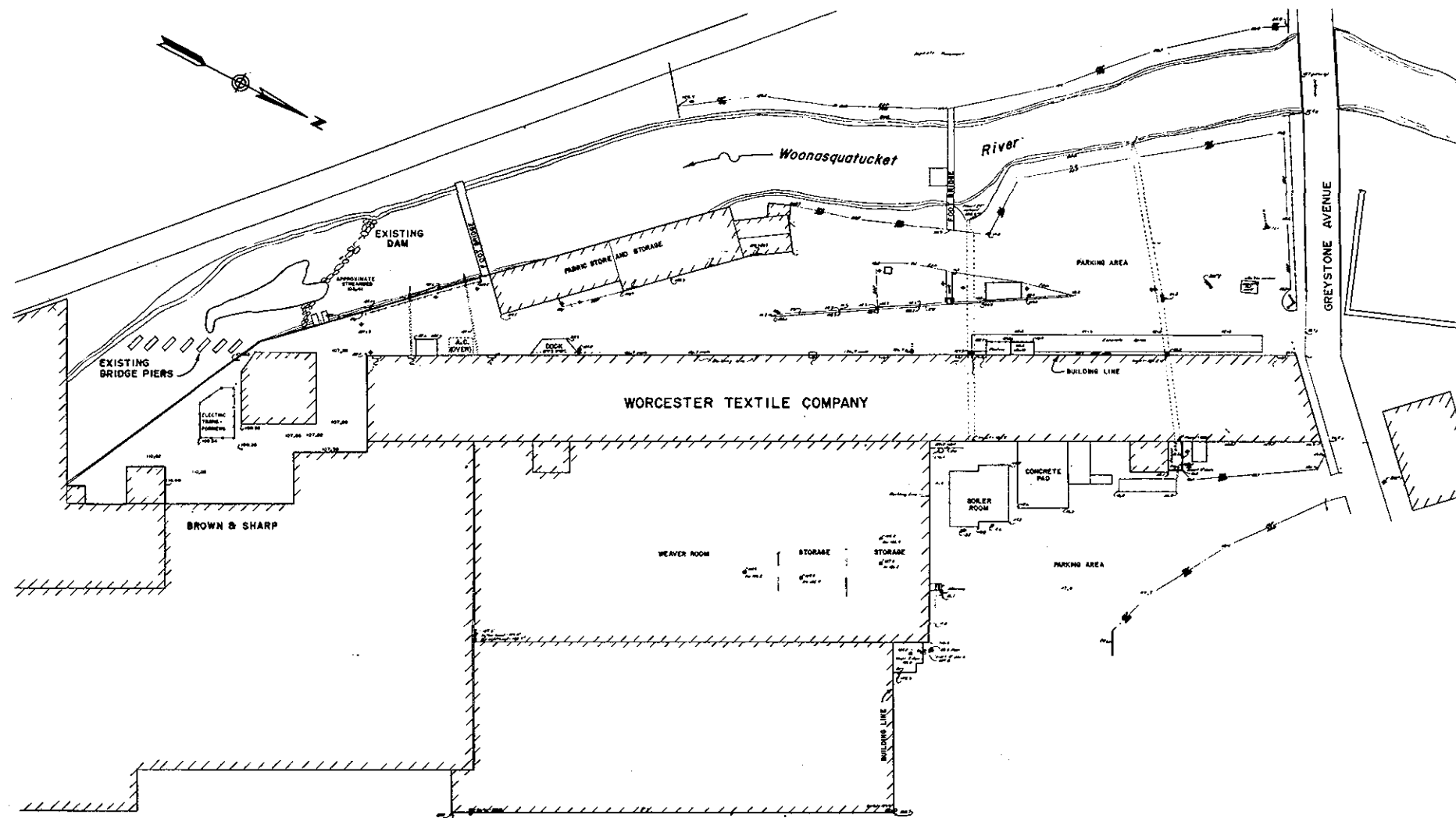
TEMPORARY AND/OR PERMANENT CLOSURES

1. Will not work for flood depths greater than 3 feet. Provide for overflow into structure at this depth. Greater depths can cause severe structural damage to walls and doors.
2. Basement or exterior walls must be essentially impermeable or can be made so.
3. A sump pump is necessary within structure to collect infiltration.
4. A good alarm system is needed during off business hours to ensure adequate time to install any temporary closures. Cooperation with neighbors is essential to warn each other of flooding.
5. Brick veneer may need reinforcing. A detailed engineering analysis is needed to ensure exterior walls can withstand anticipated hydrostatic forces.

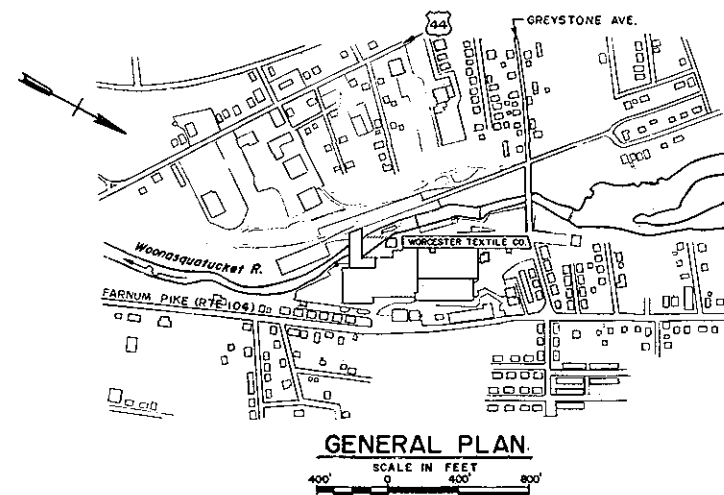
WALLS AND DIKES

1. Detailed plans should be developed by a registered engineer before any construction.
2. Wall height is generally limited to 6 to 8 feet.
3. Access openings may be required. A warning of potential flooding may be necessary to install a closure or use manual gates.
4. Permits to build in the flood plain may be required. Check with the local zoning commission and State and Federal regulatory agencies.
5. An inadequate design may result in greater damage than would have occurred without the wall or dike.
6. Sufficient pumping capacity is required to remove interior drainage from behind protection.

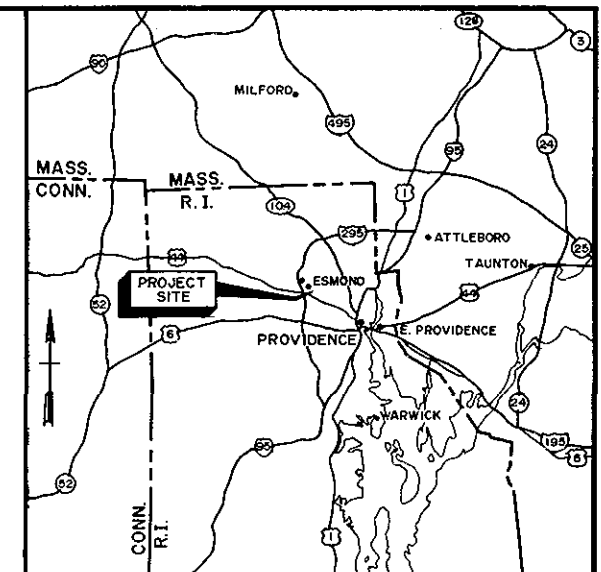




PLAN
SCALE IN FEET
0 40 80

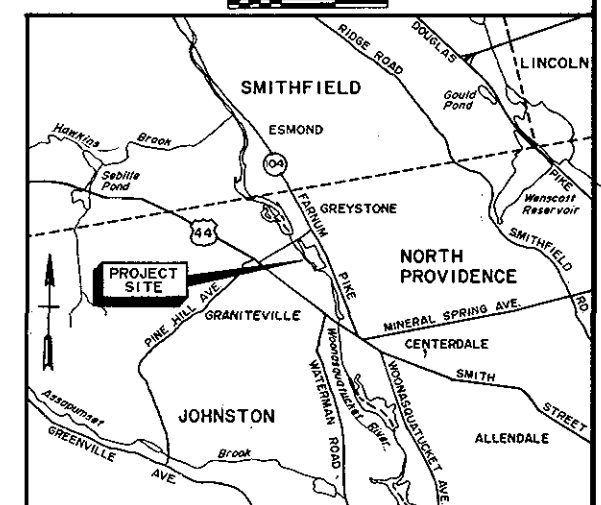


GENERAL PLAN
SCALE IN FEET
0 400 800



LOCATION MAP

SCALE IN MILES
0 5 10 MI.



VICINITY MAP

SCALE IN FEET
1000' 0 1000' 2000' 3000'

NOTES

1. Plan developed based on Corps visual field reconnaissance and plan of Worcester Textile Co. dated August 1982, by Richard E. Danielson, Registered Land Surveyor, Greenville, R.I.
2. Datum Plane: Mean Sea Level (m.s.l.) (elevations in feet)
3. The location of any subsurface features shown on this plan is approximate. Not all subsurface structures are shown on this plan. Any excavation in the area shown on this plan must be preceded by coordination with all utility companies and appropriate local and state officials to determine locations of subsurface utilities, drains, etc. Locations of drains within building lines are for reference only. They are not to scale.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

FLOOD PLAIN MANAGEMENT TECHNICAL ASSISTANCE

WOONASQUATUCKET RIVER

NORTH PROVIDENCE, RHODE ISLAND

SCALE: AS SHOWN

DECEMBER 1982

effects of the many ponds and reservoirs upstream which modify peak floodflows.

B. Climatology

The Woonasquatucket River watershed lies within the southeastern New England region, a humid area with an average annual precipitation of between 39 and 45 inches which is evenly distributed throughout the year. It has a variable climate characterized by frequent but generally short periods of precipitation produced by local thunderstorms and by intense "lows" of tropical and extratropical origin that move northeasterly up the coast. The area also lies in the path of the prevailing "westerlies" which generally travel across the country in an easterly or northeasterly direction producing frequent weather changes. Due to Narragansett Bay's moderating effect, the watershed escapes the severity of cold and greater depths of snowfall experienced in the higher elevations of the interior areas of New England.

The average annual temperature in the watershed is about 50° Fahrenheit. Extremes in temperature range from occasional highs of 100°F to lows of -15°F. Freezing temperatures may be expected from the latter part of October until the middle of April.

C. Streamflow and Flood History

The US Geological Survey has recorded flows on the Woonasquatucket River on a continuous basis from 1942 to 1981 at Centerdale, Rhode Island. The drainage area at the gage is 38.3 square miles. The gage is located about 2,000 feet downstream of Worcester Textile Company.

The average annual runoff, as recorded at Centerdale, is 72.3 cfs which is equivalent to 25.6 inches of runoff or about 57 percent of the mean annual precipitation. The peak recorded flow at Centerdale was 1,440 cfs in March 1968. The mean, maximum and minimum monthly runoff at Centerdale is listed in Table 2. Peak discharges at the gage are listed in Table 3.

Floods can occur any season of the year on the Woonasquatucket. It appears as though high flows have occurred as a result of high volume runoff, rather than as a result of high intensity short duration rainfall. It is believed that this is due to the relatively large amounts of available upstream storage. Three of the most recent floods on the Woonasquatucket River occurred in March 1968, January 1979 and June 1982.

Precipitation during March 1968 in eastern Massachusetts and Rhode Island was considerably above normal. The US Weather Bureau reported that in much of the area, March 1968 was one of the wettest Marches of record,

TABLE 2

MONTHLY RUNOFF
WOONASQUATUCKET RIVER AT
CENTERDALE, RHODE ISLAND
39 Years Record
(D.A. = 38.3 Square Miles)

<u>Month</u>	<u>Mean</u> (cfs)	<u>Maximum</u> (cfs)	<u>Minimum</u> (cfs)
January	57.8	212	30
February	49.8	129	32
March	193.0	476	75
April	134.0	304	64
May	98.1	235	44
June	47.5	77	35
July	24.7	33	15
August	21.7	28	18
September	69.2	120	7
October	58.6	159	22
November	49.0	105	22
December	82.5	154	33

TABLE 3

PEAK DISCHARGES AT
WOONASQUATUCKET RIVER AT
CENTERDALE, RHODE ISLAND
 (D.A. = 38.3 Square Miles)

<u>Date</u>	<u>Peak Discharge (cfs)</u>	<u>Date</u>	<u>Peak Discharge (cfs)</u>
Mar 1936	1,000	13 Mar 1962	554
22 Mar 1942	414	10 Nov 1962	351
12 Dec 1942	370	21 Jan 1964	644
14 Mar 1944	268	25 Feb 1965	636
30 Nov 1944	409	14 Feb 1966	286
10 Jan 1946	258	26 May 1967	870
3 Mar 1947	322	18 Mar 1968	1,440
17 Mar 1948	543	26 Mar 1969	789
6 Apr 1949	208	11 Feb 1970	910
23 Mar 1950	349	4 Mar 1971	342
3 Apr 1951	497	3 Mar 1972	1,020
11 Mar 1952	496	7 Dec 1972	812
16 Mar 1953	728	17 Dec 1973	637
11 Sep 1954	1,100	3 Apr 1975	550
18 Dec 1954	605	28 Jan 1976	901
17 Oct 1955	959	23 Mar 1977	617
6 Apr 1957	470	26 Jan 1978	1,040
27 Jan 1958	484	25 Jan 1979	1,300
6 Mar 1959	580	22 Mar 1980	691
19 Feb 1960	443	26 Feb 1981	294
17 Apr 1961	454	Jun 1982*	1,330

*Continuous record discontinued after water year 1981, however, peak discharges estimated by USGS.

with totals as high as 7 to 12 inches. Most of the precipitation fell during two storms - the first on 12-13 March, the second on 17-19 March. The total rainfall for the two storms as recorded at Providence was 7.83 inches. In addition, the season of the year - prior to the start of the growing season - increased the magnitude of flood peaks and volume of runoff. The Woonasquatucket River experienced the greatest flow in the 42-year period of record at the Centerdale gage. A peak flow of 1,440 cfs was recorded on March 18, 1968.

A flood during January 1979 was the result of two rainfall events occurring 4 days apart following a period of above normal precipitation and temperatures. Rainfall at Providence, for the month was 11.6 inches or about 3 times the normal. On the 21st, 2.7 inches of rain was recorded at Providence in a 24-hour period followed by 2.6 inches in a 24-hour period on the 25th. The Woonasquatucket River crested on the 25th with a flow of 1,300 cfs.

The June 1982 flood was also the result of two rainfall events occurring 2 days apart. On June 2, Providence experienced 2.9 inches of rainfall followed by 5.14 inches on 4-6 June. Of this 5.14 inch total, 2.97 inches fell on June 5. The Woonasquatucket crested with an estimated flow of 1,330 cfs.

D. Flood Frequencies

The Woonasquatucket River USGS gage at Centerdale, Rhode Island is located about 2,000 feet downstream of Worcester Textile Company and measures runoff from 38.3 square miles. The gage has a continuous record from 1942 through 1981 and the peak discharge of June 1982 has been estimated by the USGS. Discharge frequencies for the river at Centerdale were developed by statistical analysis of recorded annual peak flows using a Log Pearson type III distribution. The mean log, standard deviation and adopted skew coefficient for the Woonasquatucket River at Centerdale are 2.7522, 0.211 and 0.5, respectively.

A minimum design flood of 2,000 cfs was selected for determining minimum top elevations for flood control measures at the Worcester Textile Company. This flow represents about a 1 percent chance flood (100-year) event and is considered the minimum practical design for flood protection at the Worcester Textile Company. It must be noted that the 100-year frequency event can be exceeded by floods of greater severity. Although floods of a greater magnitude occur infrequently, severe damage would result.

Flood profiles for the Woonasquatucket River at Worcester Textile Company in Centerdale are shown on Plate 3. Profiles were computed by standard backwater procedures using a minimum of river cross sections and the computer program HEC-2, developed by the Hydrologic Engineering Center in Davis, California. The computer model was calibrated against estimates of the March 1968 historic flood elevation. Backwater computations were made for a range of floods using a Manning's "n" of 0.04 for channel and 0.05 for the overbanks. Assumed contraction and expansion coefficients were 0.1 and 0.3, respectively. Downstream tailwater ratings were determined from flood profiles computed by the Soil Conservation Service, in connection with a Flood Insurance Study for North Providence (Centerdale).

The flood elevation at the Worcester Textile Company facility corresponding to a stream flow of 2,000 cfs was determined to be 110 feet above National Geodetic Vertical Datum (NGVD). A flood damage reduction alternative offering a level of protection equivalent to a 100-year frequency flood event would require protection to this elevation.

Flood waters for an event of this magnitude stay within the bank of the Woonasquatucket River from the Greystone Avenue bridge to the south end of the fabric store. In this reach a 24-inch diameter culvert running from a drain near the office to the river backs up causing flooding in the plant. No overland flow of flood water is present in this reach, unless of course an event of greater severity occurs. The main area of concern is the stretch of river between the fabric store and Brown & Sharpe Company. The riverbank in this stretch is at an elevation of 107.5 feet NGVD, resulting in overtopping by the 100-year flood of 2.5 feet. The plant is affected by flooding from the office entrance to the south end of the building, a length of about 450 feet. The ground elevations of doorways in this area are 107.4, 107.5, and 108.3 feet NGVD, resulting in flood depths at entrances to the plant of 2.6, 2.5, and 1.7 feet, respectively.

VI. FORMULATION OF PLANS

1. Walls and Levees

A plan of improvement for flood control at the Worcester Textile Company plant could include construction of floodwalls, installation of sluice gates on storm drains, a low lying sump area and portable pumps to remove interior drainage and a low level berm to divert incoming local drainage. Three alternative alignments for a wall and/or levee flood protection system were developed for this location. Each wall and/or levee scheme would offer protection up to elevation 110 feet NGVD, the 100-year flood elevation, with an additional 1 foot of freeboard.

In any wall and/or levee alignment, interior runoff along with plant process water would have to be collected and pumped during high river stages. One method of collection would be to run an interceptor line from the

24-inch drain, adjacent to the office entrance, south through the driveway, intercepting the drain adjacent to the loading dock and ending in a sump located near the floodwall. Such an interceptor line would be a 24-inch diameter pipe tying into the 24-inch pipe adjacent to the office at an invert elevation of 104.5 feet NGVD and continuing south under the driveway on a constant slope tying into the drain next to the loading dock and terminating in a sump at elevation 103.5 feet NGVD. This line would have a total length of about 450 feet, an average slope of .0023 ft/ft and a capacity of about 10 cfs.

The total drainage area contributing to this system would be about 3.1 acres. It is understood from the plant engineer that an average of 40,000 gallons per day of processed water is returned to the river. Therefore, assuming one inch per hour runoff per acre, a total pumping capacity of 3 cfs would be required assuming no ponding of runoff. This pumping capacity could be reduced if an amount of temporary ponding could be accepted. An additional low level gravity drain would be required from the sump to the river to drain local runoff during low river stages. This gravity drain would also require a positive shutoff to prevent high river stages from backing up into the sump.

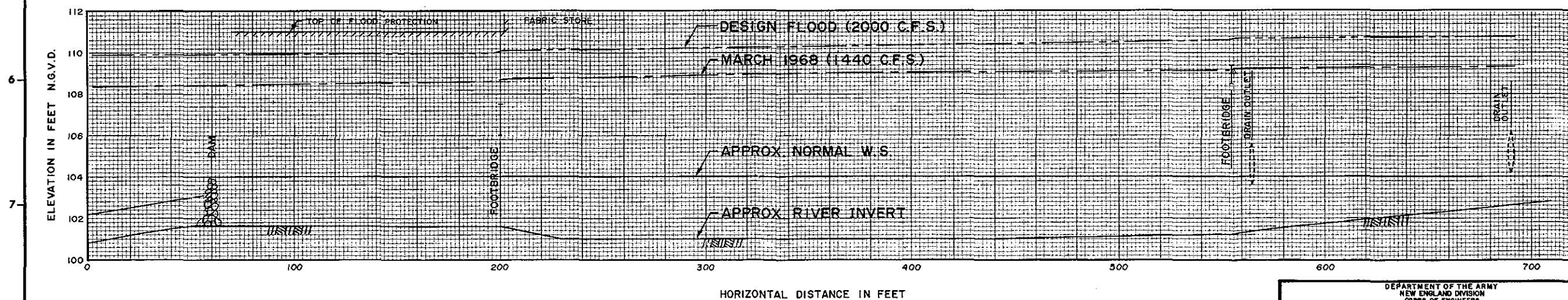
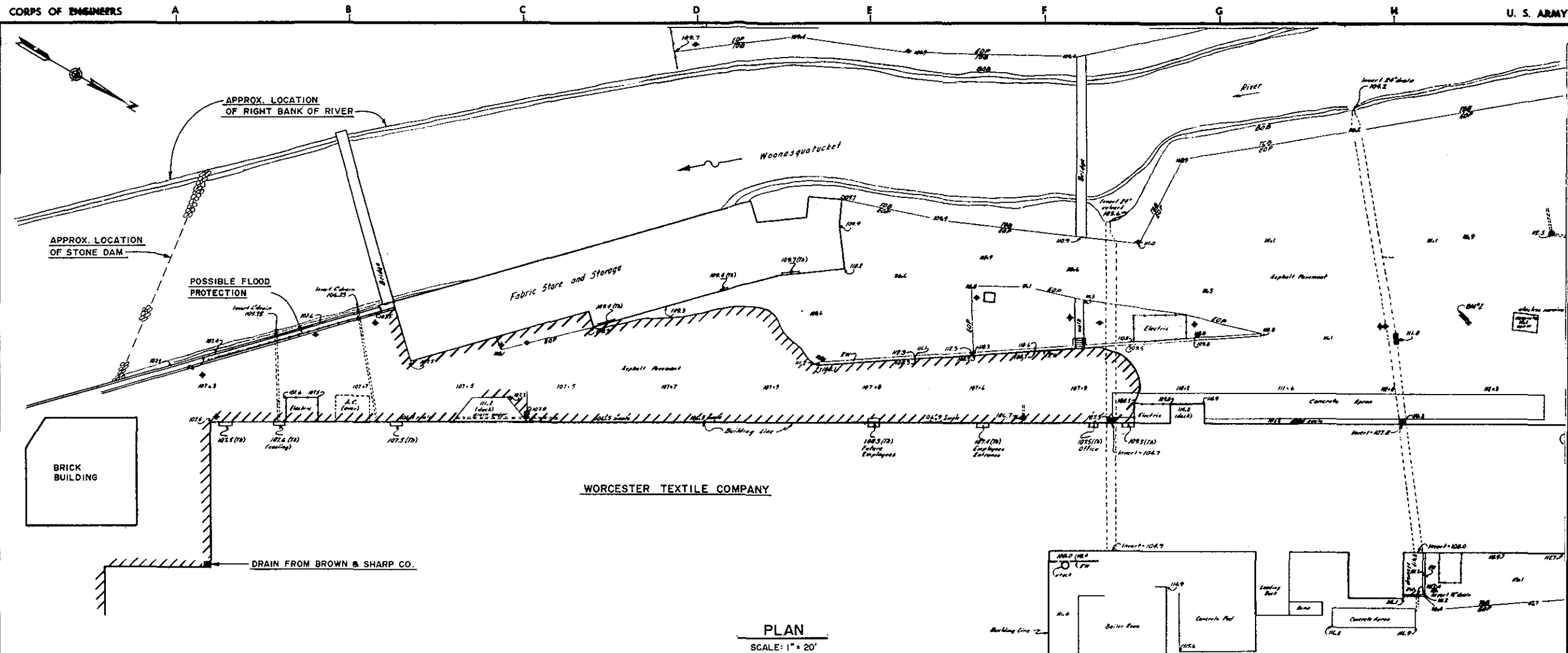
For all alignments not being tied into the southwest corner of the main building, additional runoff would have to be collected from the drain presently coming from the Brown and Sharpe Manufacturing Company. Data available does not indicate the contributing drainage area at this point or the amount of process water entering from Brown and Sharpe. These points should be thoroughly investigated prior to tying runoff from this source into the above mentioned interior drainage control system.

The present drainage culvert adjacent to the office entrance and draining westerly towards the river is very low with respect to the water surface elevations in the river. This system would require complete removal or a positive shutoff valve preventing riverflow from backing up through the present drain system. A positive closure sluice gate plus flap gate would be recommended if temporary closure is chosen. All other connections draining to the river would require similar type positive shutoffs or complete closure.

For each alignment a relatively small berm would be required at the north entrance to the parking lot and driveway to prevent surface runoff coming down Greystone Avenue from entering the Worcester Textile Company property. The berm would require a height of only a few inches and a length of approximately 50 feet. Its function would be to direct surface runoff past the driveway along Greystone Avenue to the Woonasquatucket River. A summary of the wall/levee alignments considered as potential solutions to the flood problems at the Worcester Textile Company follows.

Alternative A

This alternative consists of approximately 230 feet of gravity wall set on the riverbank and extending from the fabric store to the ledge



NOTES

△ EST. MARCH 1968 HIGHWATER

APPROX. FLOOD LIMITS
MARCH 1968 & JUNE 1982

GRAPHIC SCALE

1" = 20' 0' 20' 40'

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

FLOOD PLAIN MANAGEMENT TECHNICAL ASSISTANCE

WOONASQUATUCKET RIVER
NORTH PROVIDENCE, RHODE ISLAND
PLAN & PROFILE

SCALE: AS SHOWN

DECEMBER 1982

outcrop south of the fenced off electric transformer area. The wall would be constructed of large mass concrete blocks (5' x 3' x 3') backed on the land side by an earthen embankment. The top of this wall would be at elevation 111 NGVD, protection provided from the 100-year frequency flooding event (elevation 110 NGVD) with an additional foot allowed for freeboard.

Other components are required in order to develop an effective flood damage reduction plan. The building housing the fabric store requires waterproofing on its rear wall facing the Woonasquatucket River to elevation 111 NGVD and a short section of gravity wall would be placed to protect the rear of a small wooden structure at the north end of the fabric store. The parking lot adjacent to the north end of the fabric store would be built up to elevation 111 NGVD. This would be accomplished with a small berm extending from the fabric store to a location in the parking lot with an elevation greater than 111 NGVD.

Interior drainage would be handled in the manner discussed previously. All existing drainage would be diverted into a 24" diameter interceptor drain which would connect to a gravity discharge at a sump at the south end of the main plan building. A sluice gate would be provided in the sump to prevent backup through the gravity drain during period of high flows. A portable trailer mounted diesel pump with a 3 cfs capacity would be used to discharge interior drainage. All existing drains would be tied to the new interceptor and any fire hydrants would be moved to the land side of the wall. This system will control interior drainage with a limited amount of ponding.

A plan of this alignment is shown on Plate 4 and a breakdown of approximate implementation costs is given in the following table.

TABLE 4
SUMMARY OF COSTS
ALTERNATIVE A - FLOODWALL

<u>Item</u>	<u>Cost</u>
Floodwall	\$16,000
Waterproofing (Fabric Store)	3,000
Interior Drainage (Including pumps, interceptors, etc.)	45,000
Landscaping	1,000
20% Contingency	<u>13,000</u>
	\$78,000

Alternative B

The alignment of this alternative is the same as that in Alternative A, except that a concrete T-wall is used instead of the large concrete blocks and earthen embankment. The wall evaluated for this alternative would replace the existing retaining wall and provide protection against possible erosion as well as flooding. The wall would have a top elevation of 111 feet NGVD, offering 100-year protection with an additional one foot of freeboard. The concrete floodwall in this alternative is more expensive than that in the first alternative, but the cost of other items in the estimate remain unchanged. This alternative is displayed on Plate 5 with a summary of approximate costs in Table 5.

TABLE 5

SUMMARY OF COSTS
ALTERNATIVE B - T-WALL

<u>Item</u>	<u>Cost</u>
Floodwall	\$107,000
Waterproofing (Fabric Store)	3,000
Interior Drainage (Including pumps, interceptors, etc.)	45,000
Landscaping	1,000
20% Contingency	<u>31,000</u>
	\$187,000

Alternative C

The third alternative once again entails the use of large mass concrete blocks backed by an earthen embankment, but runs on the land side of the small utility building. The utility building is the small structure between the south end of the main plant and the old railroad bridge piers in the Woonasquatucket River. A total of approximately 290 feet of gravity wall would extend southeast from the fabric store, then easterly to the northeast corner of the utility building, and finally in a southeasterly direction tying into the ledge outcrop. This wall like the others would have a top elevation of 111 feet NGVD. The remaining items in the flood damage reduction plan (interior drainage, waterproofing, landscaping, etc.) remain the same with no changes in cost. The following table summarizes the approximate implementation costs for this alternative, while the layout is displayed on Plate 6.

TABLE 6

SUMMARY OF COSTS
ALTERNATIVE C - FLOODWALL

<u>Item</u>	<u>Cost</u>
Floodwall	\$21,000
Waterproofing (Fabric Store)	3,000
Interior Drainage (Including pumps, interceptors, etc.)	45,000
Landscaping	1,000
20% Contingency	<u>14,000</u>
	\$84,000

Alternative D

This alignment consists of approximately 90 feet of gravity wall extending along the riverbank in a southeastern direction from the fabric store. The wall then proceeds parallel to the south end of the main plant building until tying into the southwest corner of the structure. The wall would be constructed of the same materials as two of the previous alignments, large mass concrete blocks backed by an earthen embankment. A street closure is needed at the south end of the main building to allow vehicular traffic near the utility building and to the neighboring firm Brown and Sharpe Manufacturing Company. Steps must be taken when flooding becomes imminent to ensure the opening is closed before floodwaters rise. Generally, this entails the availability of equipment needed to lower wood stop logs into a channel. Also, the south end of the plant now requires waterproofing, an item not needed with the other alignments.

An important aspect of this alignment is the runoff coming from Brown and Sharpe Manufacturing Company is outside the wall, not requiring pumping during periods of flooding. The source and quantity of this flow are unknown and costs for interior drainage in the other alignments did not include provisions for handling this flow. Therefore, further investigation to determine the contributing drainage area at this point and the amount of process water existing Brown and Sharpe at this drain is not needed.

A summary of the approximate implementation costs of this alternative is given in Table 7, while Plate 7 shows the proposed alignment.

TABLE 7

SUMMARY OF COSTS
ALTERNATIVE D - FLOODWALL

<u>Item</u>	<u>Cost</u>
Floodwall	\$ 9,000
Waterproofing	4,000
Interior Drainage	44,000
Street Closure	13,000
20% Contingency	<u>14,000</u>
	\$84,000

The construction of a floodwall system including the necessary appurtenances to provide flood protection at the Worcester Textile Company facility plant may require approval and permits from agencies at the local, State and Federal level. Upon making the decision to implement a floodwall system, the consulting engineer should initiate coordination with the appropriate agencies to ensure that any eventual construction meets existing standards. Offices with potential interest at the local level could include the planning, engineering, and building departments. Agencies at the State level with responsibilities for water resource management or environmental protection may wish to review plans for any improvement of this type. Also, an inquiry should be made to determine whether a Corps of Engineers' permit is required for any placement of fill in a waterway or wetland. These contacts will assure that any potential construction satisfies safety and environmental regulations.

2. Flood Proofing

Alternative E

Another method of reducing flood damages sustained by the Worcester Textile Company is flood proofing the exterior of the structure to prevent water from entering the building. Steps required include installation of 8 watertight doorways, closure of 37 windows, application of a waterproofing sealant on exterior walls, and sump pumps to remove any seepage likely to enter the plant. The window closures and waterproofing sealant must be applied at least to elevation 110 feet NGVD to provide protection against the 100-year flood elevation. However, to ensure that flooding does not enter the plant through the window openings, closures should either be temporarily or permanently installed to elevation 111 feet NGVD. This provides an additional foot of freeboard above the design flood.

Despite the many measures designed to prevent water from entering the structure, some seepage will likely occur. An interior drainage system within the plant is necessary to address this problem and runoff from roofs of buildings and parking lots which drain through the plant. The main drainage system passing through the plant adjacent to the office entrance, receives runoff from approximately 2 acres. Therefore, a pumping capacity of about 2 cfs would be required to handle the interior drainage. Sump pumps should be placed in low lying areas where drainage collects and pumped outside the structure. Also as part of the drainage system, backup through discharge lines which exit the plant must be prevented. This entails placement of check valves to close these lines during periods of high water. The exterior portions of the property will continue to be inundated for the duration of the flood episode, but damage to the interior of the plant will be eliminated. A schematic diagram of the area and measures required for implementation of this measure, identified as Alternative E, is shown on Plate 8. An approximate breakdown of the costs associated with this plan is presented in the following table.

TABLE 8
SUMMARY OF COSTS
ALTERNATIVE E - FLOOD PROOFING

<u>Item</u>	<u>Cost</u>
Watertight Doors	\$13,000
Window Closures	3,000
Waterproof Exterior Walls	5,000
Interior Drainage	14,000
Isolate Utilities	7,000
20% Contingency	<u>8,000</u>
	\$50,000

Improvements proposed for the structure may require approval from the local zoning and building departments to ensure they meet existing regulations. Also, a registered professional engineer should perform a detailed analysis to evaluate whether the exterior walls of the structure can withstand the hydrostatic forces exerted when water builds up. Also, provisions must be made to allow overflow into the structure at greater depths of flooding. These greater depths can cause severe structural damage to walls and doors, much worse than allowing water to enter the plant.

VII. SUMMARY

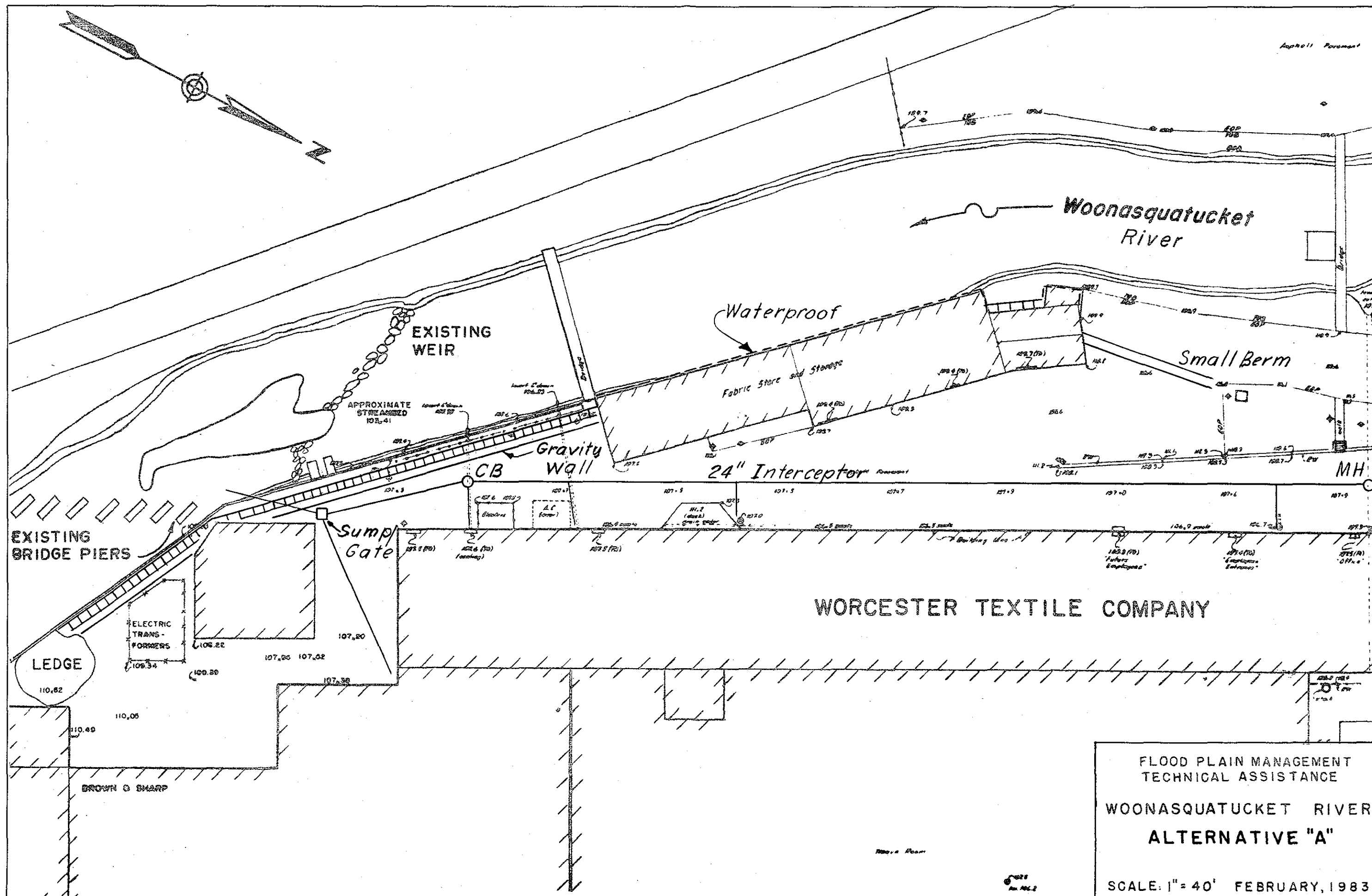
The Worcester Textile Company plant in North Providence has experienced flooding and associated damages three times within the past 15 years. Flood depths from these events within the production area in the main plant ranged from a few inches to over a foot. In the most recent flooding of June 1982, the firm had sufficient time from identification of the flood threat to actual occurrence to raise most goods off the floor and move about 10 motors out of the flooded area. However, the hard wood floor in the production area had to be replaced due to buckling. This shutdown production time resulted in a large revenue loss for the firm, much more of a monetary impact than the actual physical damage.

An analysis was performed to determine the extent of the flood problem at the subject location. The 100-year frequency flood elevation of the Woonasquatucket River in this area was found to be 110 feet NGVD, resulting in flood depths of between 2-3 feet near the plant. A flood damage reduction plan designed to offer a 100-year level of protection must offer protection to this elevation. The extent interior drainage contributes to the flood problem was identified, the discharge being equivalent to the pumping capacity required if a wall or levee system of flood protection is implemented. A problem still existing is the unknown source and quantity of discharge coming from a drain exiting the Brown and Sharpe Company near the southeast corner of the main plant. Ultimately, this data must be developed to ensure proper operation of any flood control works implemented.

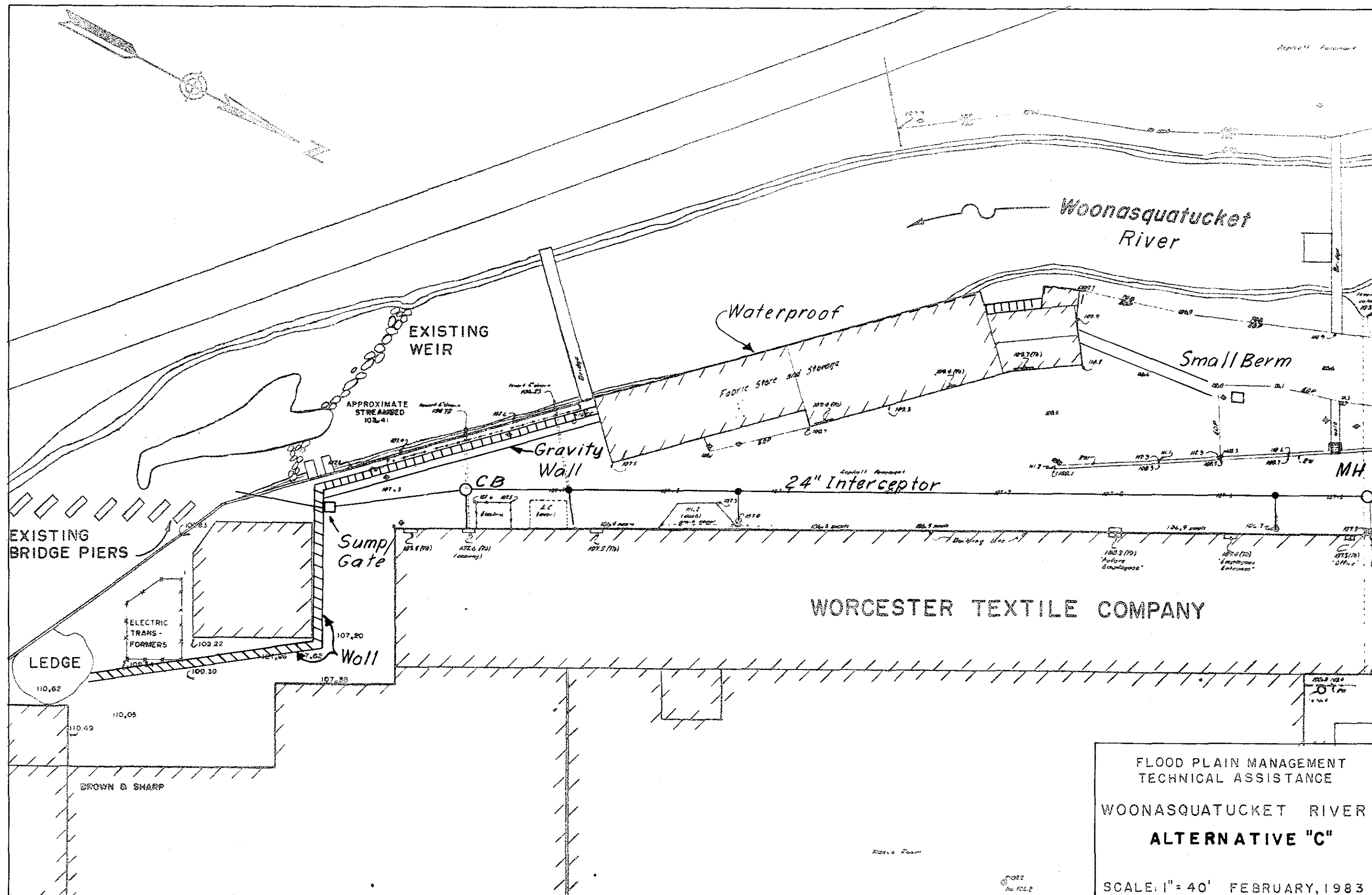
An array of flood damage reduction measures were initially viewed as potential candidates to reduce flood damage at the Worcester Textile Company plant. Based on the physical characteristics of the structure and the adjacent area, the alternatives were narrowed to two basic flood damage reduction measures, a wall and/or levee system near the river or flood proofing the exterior of the structure. Preliminary cost estimates have been prepared for four alternative wall alignments, with costs of the alternatives ranging from \$78,000 to \$187,000. The extreme range in cost for the flood-wall alternatives was due to the different alignments evaluated and varying types of walls being used.

Measures identified as being necessary to flood proof the structure are installation of watertight doors, permanent window closures, application of a waterproofing sealant on exterior walls, and sump pumps to remove any seepage likely to occur. The total cost of flood proofing the main plant has been estimated at \$50,000. This is a lower cost than any of the floodwall alternatives, but the area surrounding the plant will continue to be inundated during periods of flooding. It must be noted that all cost estimates are preliminary and likely to be refined somewhat during final design, although the order from least costly alternative to most expensive is not likely to change.

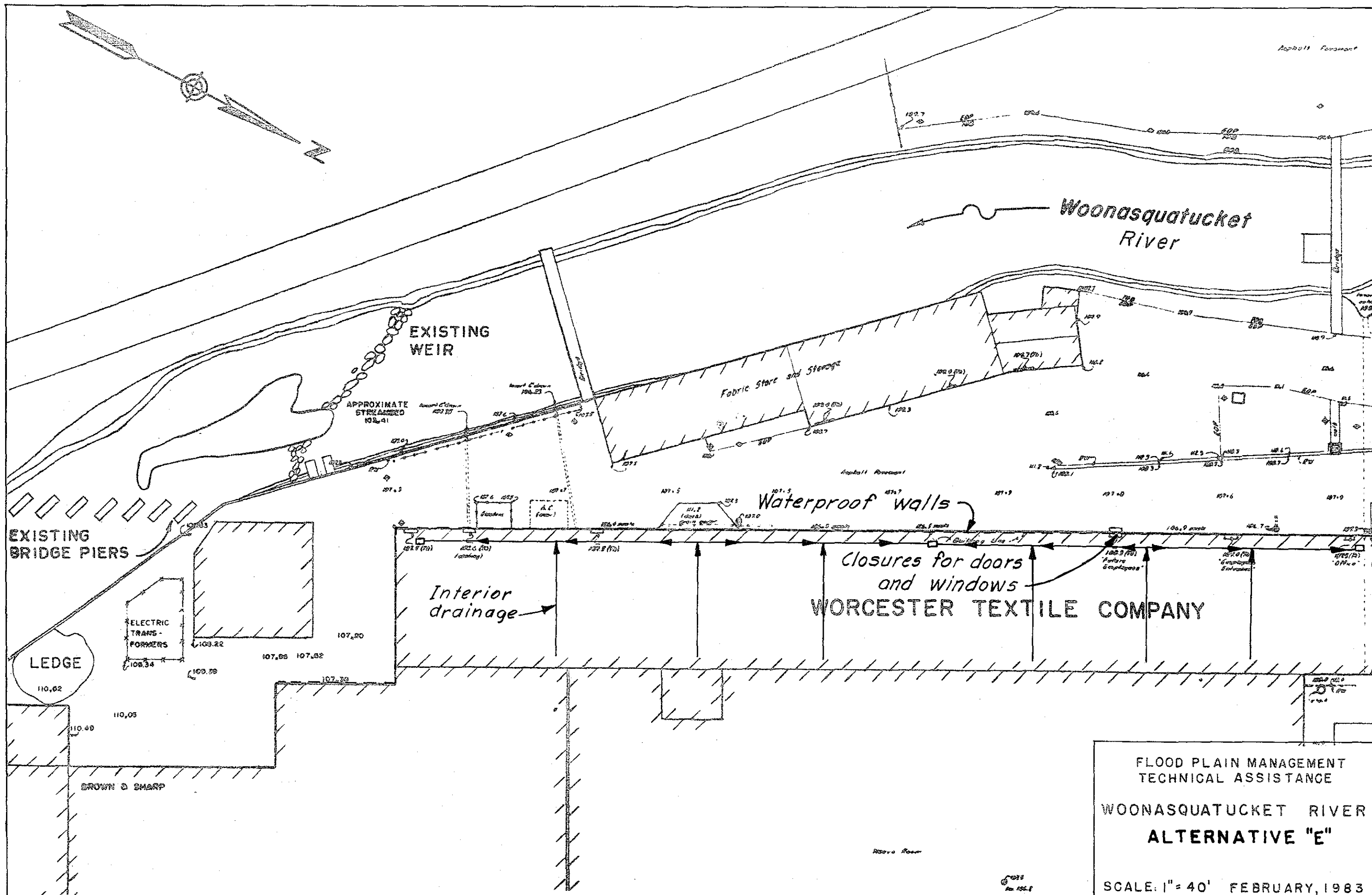
This report serves as a planning tool presenting alternative methods of reducing the impacts of flooding at the Worcester Textile Company plant. Having an array of alternatives to choose from and a preliminary cost estimate for each, the company can evaluate the merits of the various alternatives. A decision can then be made by the firm as to which alternative best addresses the problems and needs identified at the site. A recommendation concerning which alternative should be implemented is not being made because information concerning future plans of the firm are unknown. The possible expansion by the company into the adjacent building currently occupied by Brown and Sharpe has been mentioned. The status of this move has an impact on which alternative is implemented. The results of this study should be used as a planning tool, with further detailed analysis and design required before commencing construction.



FLOOD PLAIN MANAGEMENT
 TECHNICAL ASSISTANCE
 WOONASQUATUCKET RIVER
 ALTERNATIVE "A"
 SCALE: 1" = 40' FEBRUARY, 1983
 PLATE 4



FLOOD PLAIN MANAGEMENT
TECHNICAL ASSISTANCE
WOONASQUATUCKET RIVER
ALTERNATIVE "C"
SCALE: 1" = 40' FEBRUARY, 1983



FLOOD PLAIN MANAGEMENT
TECHNICAL ASSISTANCE
WOONASQUATUCKET RIVER
ALTERNATIVE "E"
SCALE: 1" = 40' FEBRUARY, 1983
PLATE 8